Application Note

Choosing Reference Points in Laser Alignment

System Recommendations

All Hamar Laser straight-line and scanning laser systems

How the Alignment System Works – Choosing Reference Points/Datum

The most important step in aligning any machinery is determining what to align it to! In other words, what are your reference points or datum?

For a centerline, such as in bore alignment, or a linear axis, such as in machine tool alignment, you will need to find 2 reference points to use for aligning or "bucking-in" the laser. Once the laser is "bucked-in" (aligned) to the reference points, you can then start measuring the other points in the linear axis (or bores) to see if they are aligned relative to the reference points.

For a surface, you will need to find 3 points. Alternatively for measuring flatness, a common reference is using earth level. Our L-730/L-740 Series lasers have level vials built into them, so either method can be used to measure flatness.

Reference Points/Datum

Points chosen on a surface, in the travel of a linear axis or in a bore that represent the starting point (reference) for which all other points on the surface will be compared. Reference points form a line or a plane that is called a *datum*.

For bore, spindle and linear travel applications 2 reference points are needed to establish a datum - for surfaces or reference planes, 3 reference points are needed.

Bad Reference Points, Bad Data

A basic rule to remember is if you have "bad" reference points, you will have "bad" data, so it is really important to think through what you want to use as a reference. You don't want to waste a lot of machine downtime trying to realign a machine to bad reference points when the machine may already be in alignment!

Level as a Reference Not Always Reliable

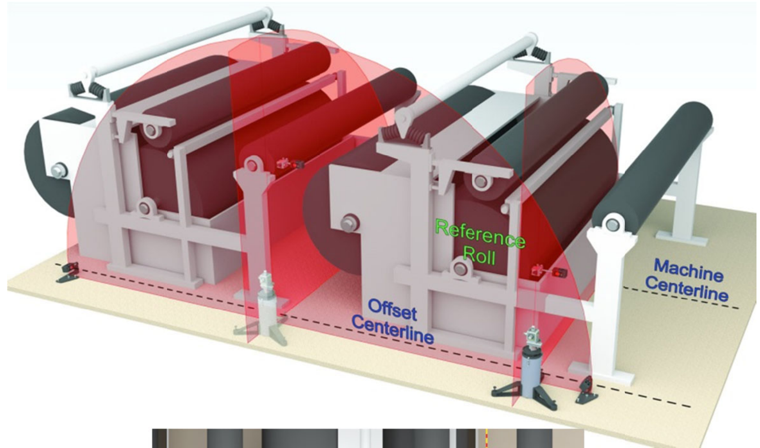
Another point to consider is earth level is not always a reliable reference to use for measuring flatness since you could have a machine bed that is not level but is flat. In this case, you will waste a lot of time releveling the bed when you don't have to.

For example, say you have a flatness tolerance of .005 in. (0.13 mm) TIR for a surface and you used the levels on the laser to measure the bed. Then let's suppose at the farthest point from the laser, you found a flatness error of .020 in. (0.5 mm). This would most certainly appear to out of tolerance, or does it? It could be the case that the surface is not level but it *is* flat (see the *Why it's Best to Use Data Analysis* graphic below)!

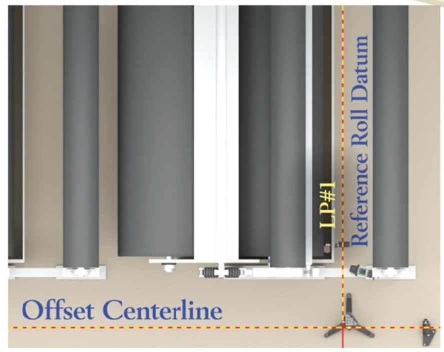
Therefore, to ensure that you are not using a "bad reference", we find it's best to use 2 reference points instead of the levels. So let's look at the same example but instead we'll use reference points on the surface itself and buck-in the laser to the 2 end points. Then we measure the points in between to look for flatness errors. In this case, it could easily be that you find a max flatness error of only .003 in. (0.076 mm) relative to the reference points. Well this would be well within your tolerance and you would save yourself a lot of time trying to relevel the bed when it was already flat!

This happen way more than you think, so always use reference points if you can!

On Process Mills:



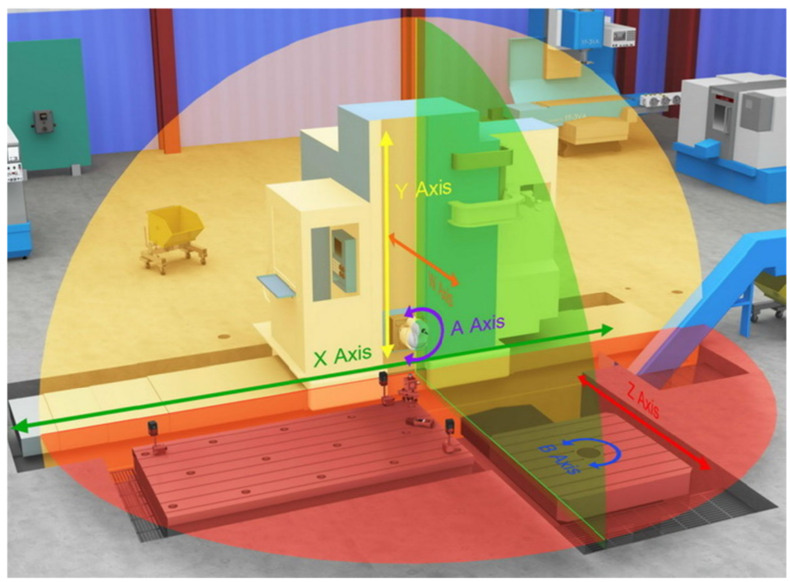
Conventional methods of roll alignment usually use floor benchmarks (monuments) at the side of the machine as references. However, we strongly believe that using a reference roll provides a more accurate reference for roll alignment and results in better alignments. This is because benchmarks are usually set in a thin concrete floor, are rarely covered, and are routinely run over and nicked. More importantly, they move with their slab of concrete and rarely hold their position relative to the mill itself. Unless checked every time they are used, benchmark will probably result in significant alignment errors.



Use a reference roll and you will never have this problem.

Fortunately, our L-742 and L-732 Roll Alignment systems offer the ability to use a reference roll or to use benchmarks if absolutely necessary.

On Machine Tools:



Machine tools are one of the most challenging applications for alignment. Typically they have tight tolerances and require multiple references that need to be considered before starting any alignment job. Using our L-743 Triple Scan® laser, for example requires 5 reference points, 3 for the horizontal (red) plane, and 2 for one of the vertical planes (either green or yellow).

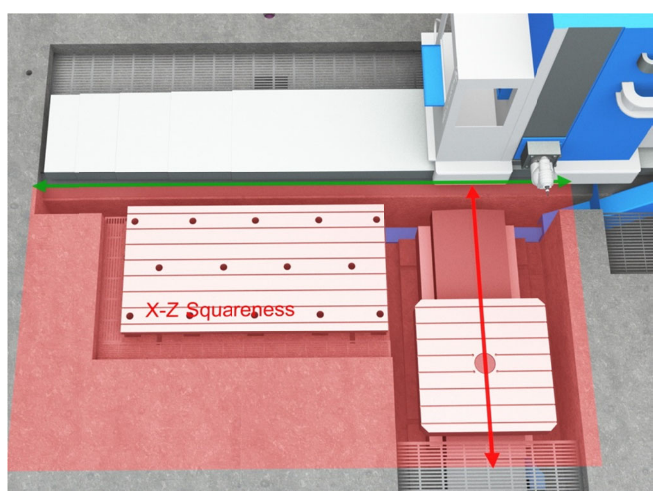
Linear Axes vs. Machine Tables

In general, it's better to use the machine linear travel as a reference versus the table. Tables can have significant flatness errors along with many dings and dents that can mess up your reference. Also since it's the linear travel that is controlling the cutting head, it's best to focus on the travel. Of course, you can use the table as a starting point but it is best practice to use the machine's linear travel as final reference and then us the least-squares, best fit analysis of the data (see below) to remove laser slope error.

Always Use Longest Distance between Reference Points

It's always a good idea to use the longest axis as the reference because it gives you the best angular accuracy. In other words, it usually a bad idea to use 2 reference points that are 5 feet (1.5 m) part to measure a surface or linear axis that is 30 feet (10 m) long.

For example, let's look at machine tool with a 5-foot (1.5 m) Y axis and a 30-foot (10 m) X axis. If you used the Y axis as the reference to measure squareness of the X axis, then you would



Horizontal Floor Mill with 30 ft X Travel and 5 ft Z Travel need to buck-in (align) the laser to the Y axis at a 5-times higher accuracy than if you had used the X axis.

So let’s say you bucked into the Y axis to .001 in (0.025 mm), and then you measured the X axis. Well at the end of your X axis, you would have an laser-setup error of .006 in. due to the laser having a slope of .001 in 5 feet (.001/5*30 = .006 or 0.025mm/1.52m*10=0.16 mm). We call this the “tail wagging the dog”! Not good.

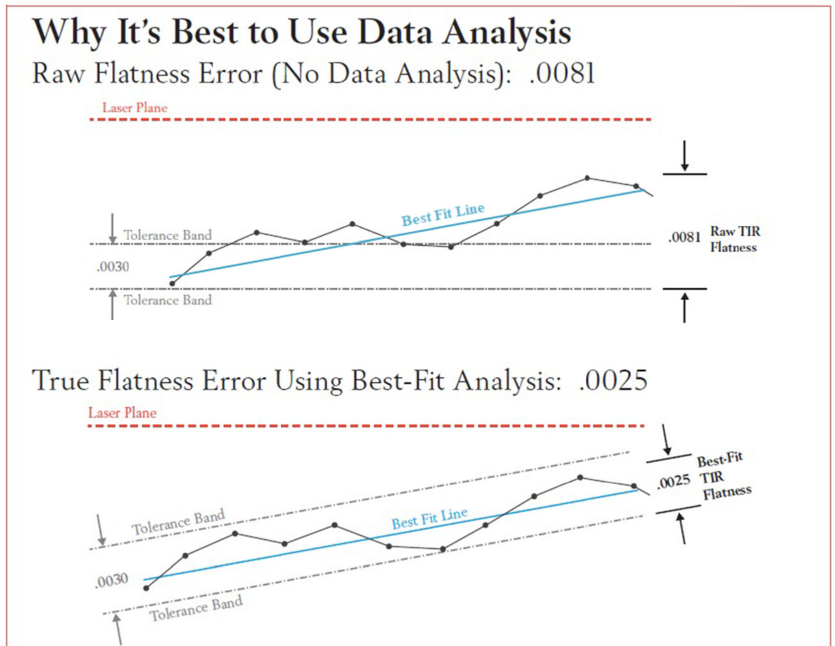
But if you use the X axis for your reference and align to the same .001 in, then the laser-setup (slope) error at the end of the Y axis will be .00017 in.(.001/30 * 5 = .00017 or 0.025mm/10m*1.5 = 0.004 mm). Much better!

Least-Squares, Best-Fit Analysis

In metrology, it is recommended that some sort of data analysis be performed on a machine's axis before proceeding to the alignment stage. All of Hamar Laser’s software uses a least-squares, best fit (Best Fit) analysis of straightness and flatness data.

This step can save countless hours aligning a machine tool that only has a couple of bad points, or perhaps from drawing a wrong conclusion from the data due to a laser setup problem.

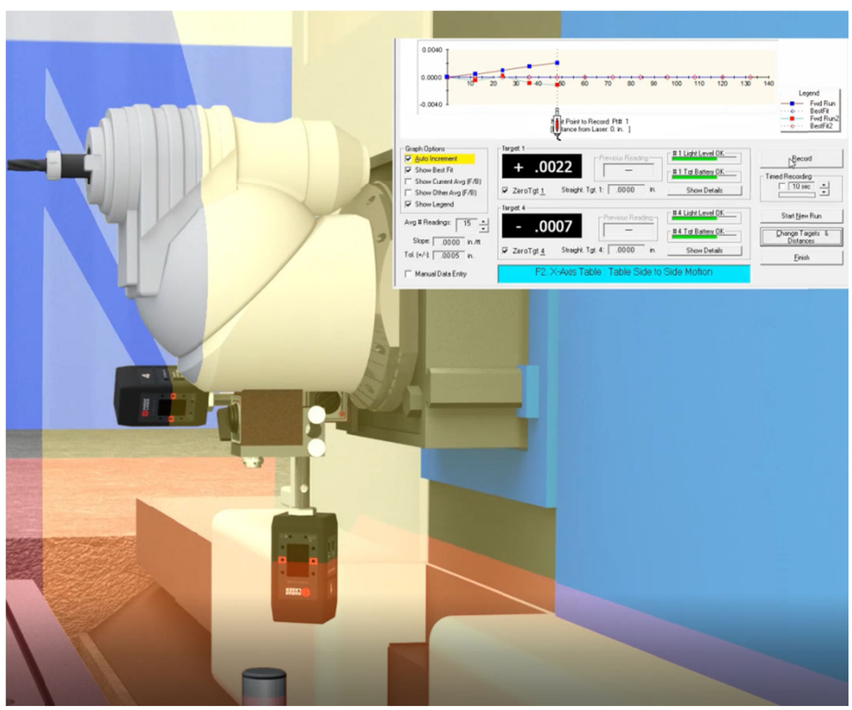
It works like this: a Best Fit line is calculated for a set of straightness (or flatness) data for a linear axis (or a best-fit plane for a surface) that “best fits” the data. The best fit line (or plane) will have a slope to it that can be used to analyze flatness/straightness data. This slope is applied to the raw data and the points are corrected to remove the slope error of the best-fit line. Then the maximum positive value (relative to the best-fit line) is added to maximum negative value (absolute value) to produce the total error or Total Indicated Runout (TIR) flatness error, which is the *true* flatness error of the surface.



In this case, the laser was level to earth but the surface was not level. By using the Least-Squares, Best-Fit analysis, which calculated a line that “best fits” the data and then compared the data points to the line, we can see that the Best-Fit (true) TIR flatness error is significantly less than the raw flatness error and is “in-tolerance”.

Best-Fit Analysis Removes Setup Errors

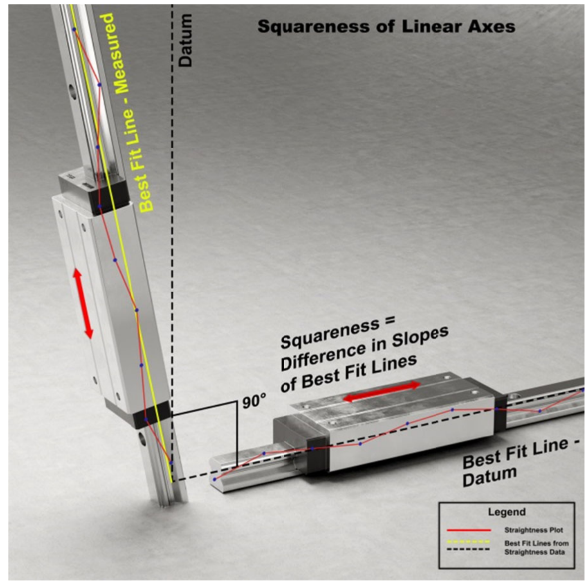
By using the Best-Fit analysis, we can also remove the slope error caused by a laser setup problem. So in the case on the machine described above, where we used the Y axis as the reference, if we used the best-fit analysis, then the laser slope error would be removed from the data and the true flatness of a surface would be determined (see the graphs in *Why It’s Best to Use Data Analysis*).



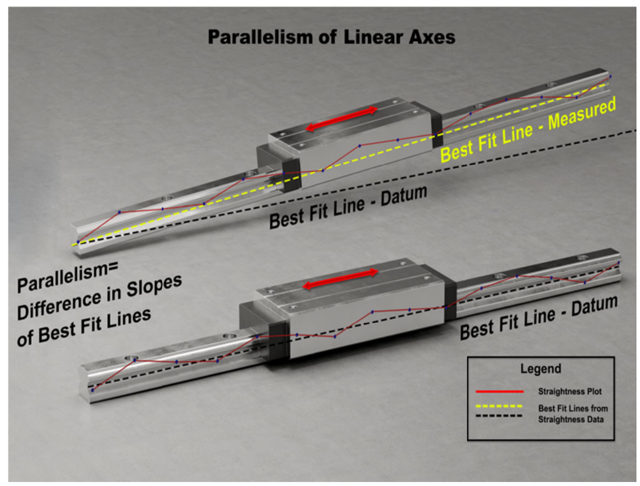
Hamar’s Machine Tool Geo Software automatically uses Best-Fit analysis of machine tool straightness data

Squareness/Parallelism Measurements Require Best-Fit Analysis

Since most axes of machine tools have straightness/flatness errors, using any 2 points on an axis as a measurement for squareness (such as the top and bottom points on the Z axis), could lead to a poor analysis. In other words, pick the top and bottom points of the Z axis to determine squareness to X and it could look to be *out* of tolerance, but pick 2 middle points and it may be *in* tolerance. This is because normally there are straightness errors in the Z axis data, which may make it very hard to pin down the true squareness error. But if you use the Best Fit analysis of the straightness data for Z axis, which gives you a slope of its Best-Fit line for Z, and then compare this to slope of Best Fit line for the X axis straightness data, then you will have the best analysis of the squareness between the 2 linear axes (all Hamar Software does this).



Using a Best-Fit Analysis for Measuring Squareness of Linear Axes



Using a Best-Fit Analysis for Measuring Parallelism of Linear